Geographical Database Integrity Validation

ODURF Project # 193711

NASA NAG-1-2199

August 24, 2000

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Introduction

Background

Airport Safety Modeling Data (ASMD) was developed at the request of a 1997 White House Conference on Aviation Safety and Security. Politicians, military personnel, commercial aircraft manufacturers and the airline industry attended the conference. The objective of the conference was to study the airline industry and make recommendations to improve safety and security. One of the topics discussed at the conference was the loss of situational awareness by aircraft pilots.

Loss of situational awareness occurs when a pilot loses his geographic position during flight and can result in crashes into terrain and obstacles. It was recognized at the conference that aviation safety could be improved by reducing the loss of situational awareness. The conference advised that a system be placed in the airplane cockpit that would provide pilots with a visual representation of the terrain around airports. The system would prevent airline crashes during times of inclement weather and loss of situational awareness.

The system must be based on accurate data that represents terrain around airports. The Department of Defense and the National Imagery and Mapping Agency (NIMA) released ASMD to be used for the development of a visual system for aircraft pilots. ASMD was constructed from NIMA digital terrain elevation data (DTED).

Purpose

The purpose of this report is to determine the accuracy of ASMD, to support the goal of the national aviation program and to increase safety and security around airports. An aspect of the aviation safety program is to provide commercial aircraft pilots with a real time visual system that displays the airspace of terrain impacted (surrounded by hazardous geographical landforms such as mountains) airports. Pilots would utilize the system during times of inclement weather when they are unsure of their geographical location.

Objectives

The objective of this report is to determine the accuracy of the ASMD. This report has three primary goals: identify a database to be used as a benchmark for comparison to the ASMD, develop a methodology to determine the accuracy of the ASMD and formulate information extraction techniques to reduce the amount of data utilized during the study. The secondary goal of this report is to determine other airports that should be included in the study of ASMD accuracy.

Benchmark Database

A literature review was conducted to find a database that can be used as a benchmark (accepted true value). The ideal benchmark database will have a scope that covers the continuous United States including Alaska and Hawaii. The data density of the benchmark database should be higher than the data density of the ASMD. The data density is referred to as the number of elevations over a geographic region The United States Geologic Survey (USGS) was chosen as the benchmark database.

Error Measurement

This project developed a method to measure the error in the ASMD. An error matrix was acquired by taking the difference of the ASMD and the benchmark database. A technique was developed to measure the error matrix of the databases since these two databases have different data densities and reference points.

Using tradeoffs in sample size and data density, a comparative of average error was developed using the two databases. A statistical analysis of the error was made and

conclusions were drawn from the information. Histograms were created to visually display the ASMD error of the airports.

Data Reduction

Methods were developed to reduce the amount of data used in the study. The principles of data mining were applied to the data to extract useful information. Algorithms and neural networks were utilized during the development of data reduction techniques. Other areas of study include accuracy requirements for the visual display, resolution with respect to sample size for the visual display and alternative methods for measuring accuracy.

Databases

The ASMD database is the source data that was used to develop the real time visual system for commercial aircraft pilots. The derivation and format of the ASMD database and the benchmark database must be understood before a methodology can be developed to make error measurements. Data accuracy and data availability are criteria that must be taken into consideration during the selection of a benchmark database. Both criteria are reviewed in this report

ASMD

ASMD data was developed for use as the source data of a real time visual system for commercial aircraft pilots. ASMD was synthesized from DTED1 data and contains data for one hundred fourteen terrain-impacted airports in the United States.

ASMD contains data in two categories: ASM12 and ASM100. ASM12 contains data within a six mile radius of the airport reference point (ARP) while ASM100 contains data within a fifty mile radius (one hundred mile diameter) of the ARP. The ARP is the geographic center of an airport's runways. This radius is illustrated in **Figure 1**.
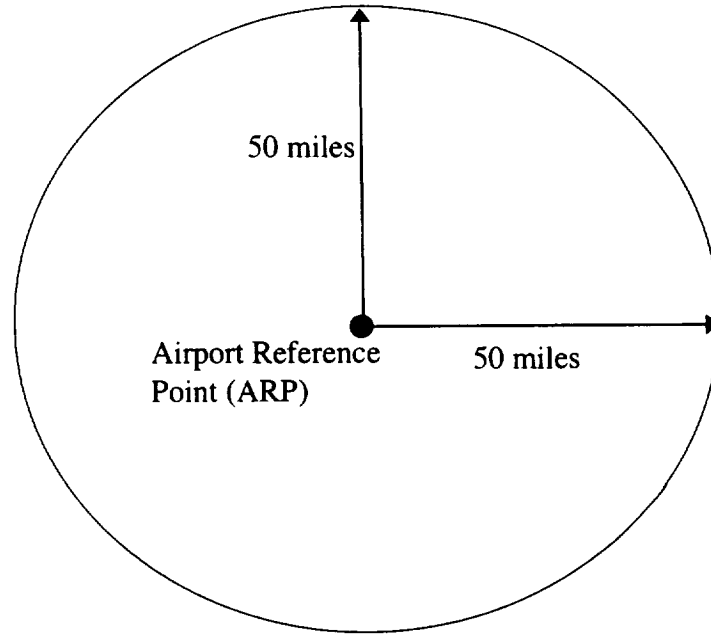
Figure 1 Airport Reference Point

The scope of this report is to analyze the data within a thirty mile radius of the

ARP. Since the ASM12 data file does not cover the entire geographic area, it was

excluded from this report and the ASM100 data file was utilized for each airport analyzed

in this study. For the purpose of clarity whenever ASMD is used in this report the author

is referring to the ASM100 data file.

Each ASMD data file is representative of a one degree by one degree quadrangle.

The data file for each airport contains more than two hundred thousand (200,000) cells.

Each cell is representative of a fifteen arc second by fifteen arc second (15" x 15")

geographic area. The cells are arranged in ascending order from the southwestern most

cell to the northeastern most cell. **Figure 2** describes the structure of an ASMD file.

Each data file has exactly four hundred rows and more than five hundred columns.

	1	2	•	499	500	**NE**
402						
401						
•						
•						
•						
2						
1						

SW   15" by 15" Cell
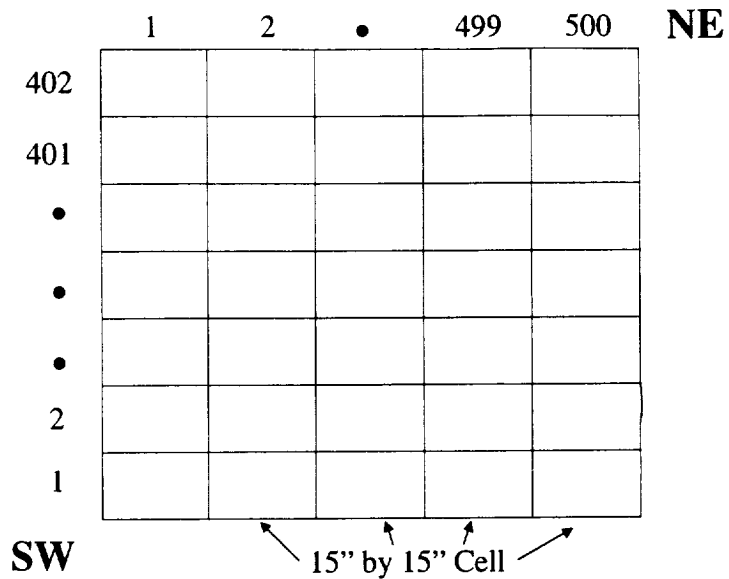
Figure 2 ASMD Cell Order

Each cell in the ASMD data file contains a latitudinal coordinate, longitudinal

coordinate and an elevation. The latitudinal and longitudinal coordinate determines the

geographic location of the cell. The elevation is the approximate vertical elevation of the

cell and is given in meters.

It is essential to understand how the approximate vertical elevation of the cell was

derived from DTED data since the approximation of vertical elevation is the primary

source of error in the ASMD database. The elevation for each cell in the ASMD data file

is actually the maximum elevation of the thirty-six elevation posts located within the cell

Figure 3 describes the structure of an ASMD cell.

15" by 15" Cell

Elevation Post

Figure 3 ASMD Cell

The thirty-six elevations are DTED1 data and are organized in three arc second

(3") intervals. One of the elevations in the ASMD cell is recorded as the elevation for the
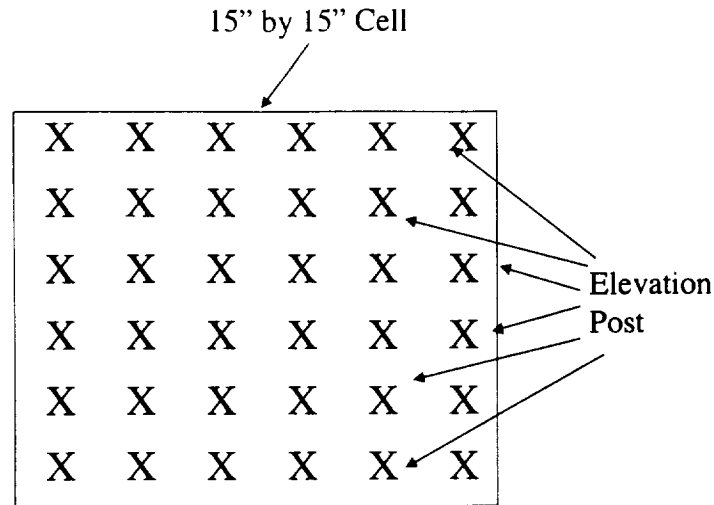
cell and the other thirty-five cells are discarded. One arc second is equivalent to thirty

meters. The fifteen arc second by fifteen arc second cell is equivalent to two hundred

two thousand five hundred square meters (202,500 m^2). The ASMD data file contains

only one elevation measurement for the entire 202,500 m^2 area.

The goal of this study is to determine how much error is associated with these

approximations and to determine if the ASMD data file is suitable for basing a real time

visual system for aircraft pilots.

Data Accuracy

The purpose of this report is to determine the suitability and accuracy of the

ASMD database for use as the source data for a real time visual system for aircraft pilots.

The elevations in the ASMD database represent only terrain elevations, they do not

contain any obstacle elevations. The vertical datum for elevation in the ASMD data is

mean sea level. The horizontal datum for ASMD data is the World Geodetic System (WGS) of 1984. The elevations do not necessarily represent the elevation at its exact horizontal position. The elevations represent an interpolated value of the surrounding terrain within the cell (ASMD CD-ROM handout).

The horizontal accuracy of the ASMD data is fifty meters. Ninety percent (90%) of the elevations are within fifty meters of its actual horizontal geographical position. The vertical accuracy of the ASMD data is thirty meters. Ninety percent (90%) of the elevations are within thirty meters of its actual elevation

Data Availability

NASA Langley Research Center supplied the ASMD data on a CD-ROM. The Department of Defense and NIMA developed the CD-ROM. The data was synthesized from DTED1 data.

The CD-ROM contains data from one hundred twenty five airports in the United States. The data is in ASCII format. **Appendix 1** contains a listing of the header of the ASM100 file for the Denver International Airport. The CD-ROM contains a text file that describes the derivation and organization of ASMD data.

USGS

After an extensive literature review it was determined that a United States Geologic Survey (USGS) Digital Elevation Model (DEM) would be utilized as the benchmark database. The USGS DEM is widely accepted as the most accurate and comprehensive geological survey of terrain in the United States. The USGS has been designated as a lead federal agency for the collection of digital cartographic data

(Standards for Digital Elevation Models). It will be explained later in this section why the USGS was selected as the benchmark database.

DEM data consist of a sampled array of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) or a geographic coordinate system (USGS Fact Sheet 102-96, April 1998). The grid cells within a DEM are spaced at regular intervals dependent upon latitude along south to north columns and than from west to east rows (Fact Sheet 102-96). The USGS uses four methods to collect DEM data: interpolations from vectors or digital line graph hypsographic and hydrographic data, the Gestalt Photo Mapper II, manual profiling from photogrammetric stereomodels and interpolation of the elevations from stereomodel digitized contours (Fact Sheet 102-96). Only the first method is used today, the other three methods have been discontinued or deactivated.

The USGS produces five types of DEM data. They are listed in **Table 1** along with coverage and spacing information. The 7.5 minute DEM will be used as the benchmark database because of its high data density and coverage of the entire United States. Data density is referred to as the number of elevation posts per geographic region. The 7.5 minute DEM has a higher data density than the other DEMs in **Table 1**. It also covers the entire geographic area within the scope of this study.

DEM Type	Coverage	Interval Spacing
7.5 minute	Contiguous United States, Hawaii and Puerto Rico	1 arc second by 1 arc second
30 minute	Contiguous United States and Hawaii	2 arc second by 2 arc second
1 degree	Contiguous United States	3 arc second by 3 arc second
7.5 minute Alaska	Alaska	Dependent upon latitude; 1 arc second (lat) by 2 arc second (long)
15 minute Alaska	Alaska	2 arc second (lat) by 3 arc second (long)

Table 1 USGS DEMs

The 7.5 minute DEM covers a 7.5 minute by 7.5 minute geographic region. The DEM corresponds to the 1:24000 and 1:25000 scale topographic quadrangle map. The 7.5 minute DEM is cast on the UTM. **Figure 4** is an illustration of the structure for a typical 7.5 minute DEM. **Figure 4** was reproduced *from Standards for Digital Elevation Models*. The elevations are organized from south to north in columns and then west to east along rows.

The data is organized at thirty-meter intervals between elevations. Some areas within the contiguous United States have ten-meter interval spacing. We will only use the thirty-meter interval spacing for consistency. Some airports only have interval spacing of thirty meters.

Data Accuracy

The elevations in a 7.5 minute DEM have units of feet or meters. The DEMs are cast on the UTM of the North American Datum (NAD) of 1927 or NAD 83 (Fact Sheet 102-96). The vertical elevations are referenced to the National Geodetic Vertical Datum of 1929.
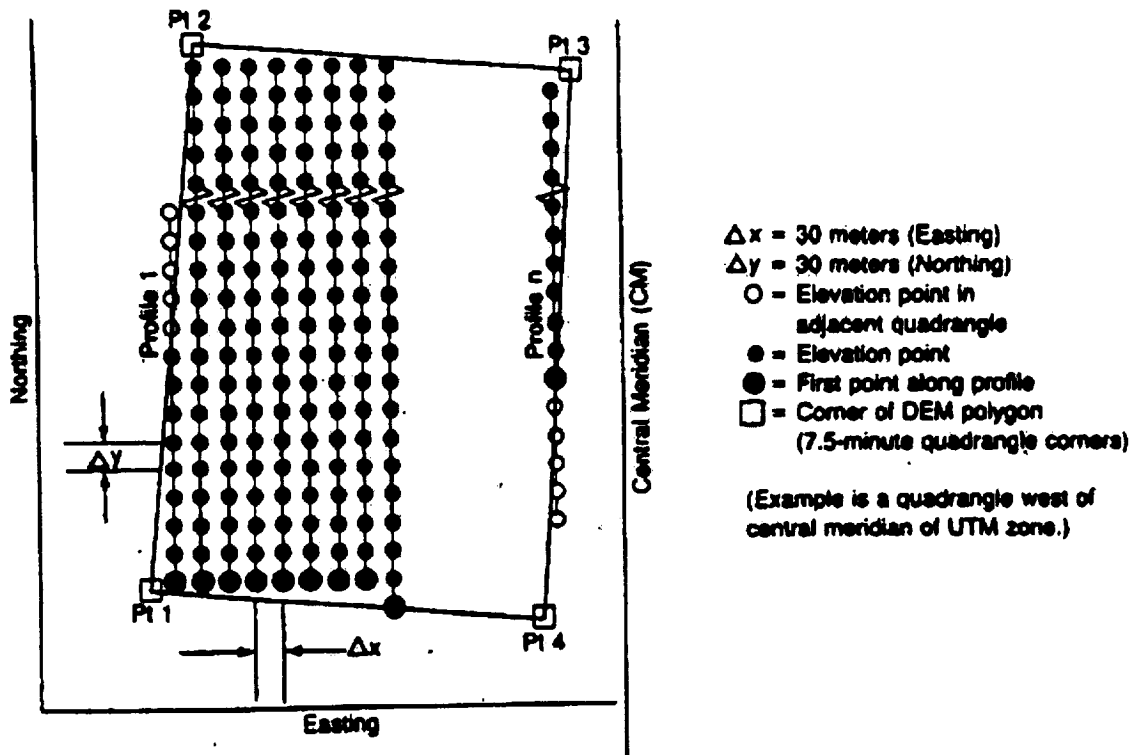
Δx = 30 meters (Easting)
Δy = 30 meters (Northing)
O = Elevation point in adjacent quadrangle
● = Elevation point
⬤ = First point along profile
☐ = Corner of DEM polygon (7.5-minute quadrangle corners)

(Example is a quadrangle west of central meridian of UTM zone.)

Figure 4 7.5 minute DEM

Root Mean Square Error (RMSE) is the criteria used to determine DEM accuracy.

RMSE is calculated by comparing linearly interpolated elevations in a DEM with

corresponding known elevations and computing the associated statistical standard

deviation. For a 7.5 minute DEM derived from a photogrammetric source, ninety percent

must have a RMSE of seven meters or better and ten percent are in the eight to fifteen

meter range (Fact Sheet 102-96). The horizontal accuracy of a 7.5 minute DEM requires

that ninety percent of all points tested must be accurate within 1/50th of an inch (.005

centimeters) on a map, which corresponds to forty feet (12.2 meters) at 1:24000 scale

Data Availability

7.5 minute DEM data can be obtained by either purchasing it directly from the

USGS or downloading it from the Internet. All of the 7.5 minute DEMs used in this

report were downloaded from the Internet. **Figure 5** is a flowchart of the process used to download the 7.5 minute DEMs in this report.
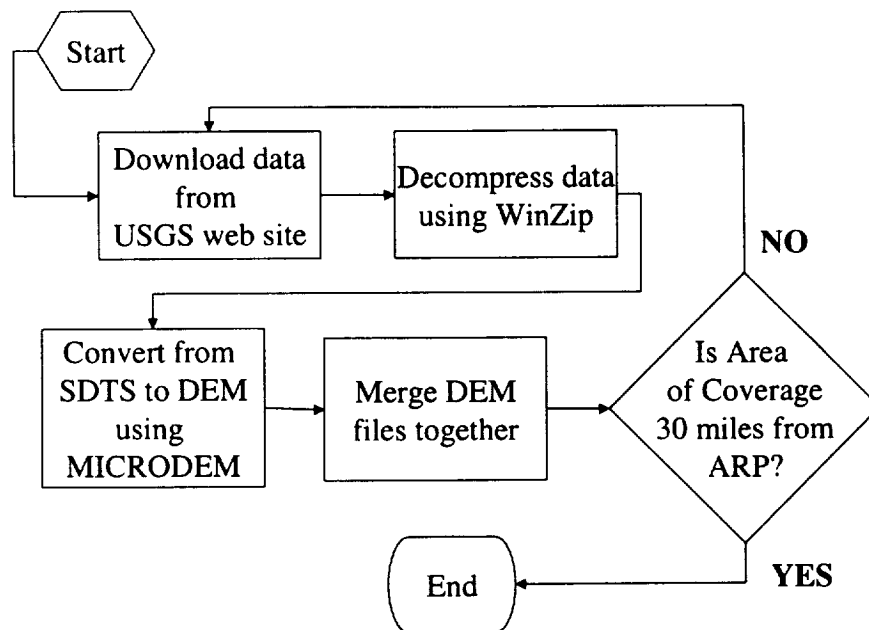
```
      ┌─────────┐
      │  Start  │
      └─────────┘

  ┌──────────────┐      ┌──────────────┐
  │ Download data│      │Decompress data│
  │    from      │─────▶│ using WinZip │          NO
  │ USGS web site│      └──────────────┘
  └──────────────┘

  ┌──────────────┐      ┌──────────────┐      ╱ Is Area  ╲
  │ Convert from │      │              │     ╱  of Coverage ╲
  │ SDTS to DEM  │─────▶│  Merge DEM   │────▶│  30 miles from │
  │    using     │      │ files together│     ╲     ARP?    ╱
  │  MICRODEM    │      └──────────────┘      ╲          ╱
  └──────────────┘

                        ┌──────────┐                   YES
                        │   End    │◀──────────────────
                        └──────────┘
```

Figure 5 USGS Acquisition Process

While downloading the data care should be taken to ensure that the file extension ".tar.gz" is maintained. Netscape Navigator and Microsoft Internet Explorer attempt to replace the ".tar.gz" file extension with the "_tar.gz" file extension. If the files are improperly renamed it will cause problems when the files are decompressed with WinZip.

The original format of the data after decompression is the Spatial Data Transfer Standard (SDTS). The DEM must be converted into ASCII format by using MICRODEM. When the DEM is being converted from SDTS format to ASCII format use the lat/long geographical system in MICRODEM to ensure the consistency of the

data file. The entire process of downloading DEMs from the Internet should be repeated

until there are a sufficient number of DEMs to cover a thirty-mile radius from the ARP.

Methodology

Table 2 compares the cell size, units, horizontal datum and vertical datum for the

ASMD data and the 7.5 minute USGS DEM. It is not possible to determine the error in

the ASMD data by taking the algebraic difference of the two databases because they have

different cell sizes and datum. A methodology was developed that does not require the

two databases to have the same cell size or datum.

Database	Cell Size	Units	Horizontal Datum	Vertical Datum
ASMD	15 " by 15 "	Meters	WGS 1894	mean sea level
7.5 minute DEM	30 m by 30 m or 1" by 1"	Feet or meters	UTM of NAD 1927 or NAD 1983	NGVD 1929

Table 2 ASMD and USGS Comparison

The methodology used to determine the error in ASMD data builds upon how the

ASMD data was derived. The elevations in ASMD data are associated with fifteen arc

second cells. The elevation of each cell is the maximum of thirty six sampled elevations

located in the cell. The methodology in this paper uses the same ASMD cell but samples

two hundred fifty six elevations located in the cell to determine the cell elevation. The

two hundred fifty six elevations will come from the USGS 7.5 minute DEM. The basis

of the methodology is that two hundred fifty six elevations are more likely to find the

maximum elevation in a cell then thirty six elevations. Figure 6 is a flowchart of the
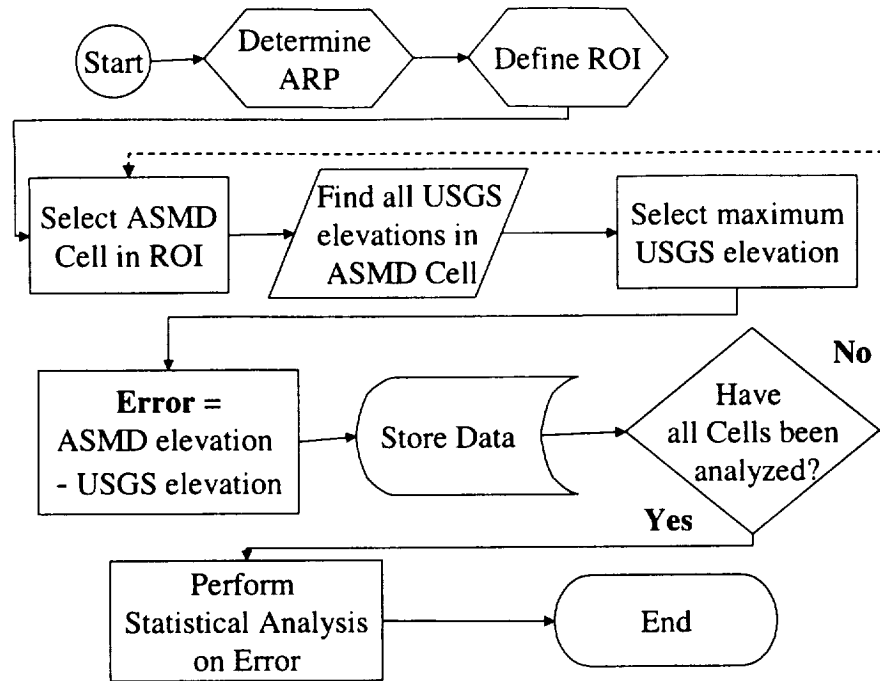
methodology.

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Figure 6 Methodology Flowchart

The first step in the methodology requires that you determine the ARP of the airport. The ARP is located in the ASMD data file. All coordinates in the ASMD data file are listed in degrees minutes seconds format (DDMMSS). The coordinates are converted to degrees format (DD.DDDD) so that they will be consistent with the format of coordinates in the USGS data file.

After the ARP is determined the region of interest (ROI) is calculated. The ROI is defined as the geographic area within thirty miles (.44706 degrees) of the ARP. Theoretically, the ROI is a circle with a thirty mile radius with the ARP located in the center. Due to computational concerns the actual ROI in this study is a square with sixty mile sides as described in **Figure 7**. This modification reduces computation time and increases the ROI. The modification will not affect the results because it does not reduce the number of ASMD cells that will be analyzed.
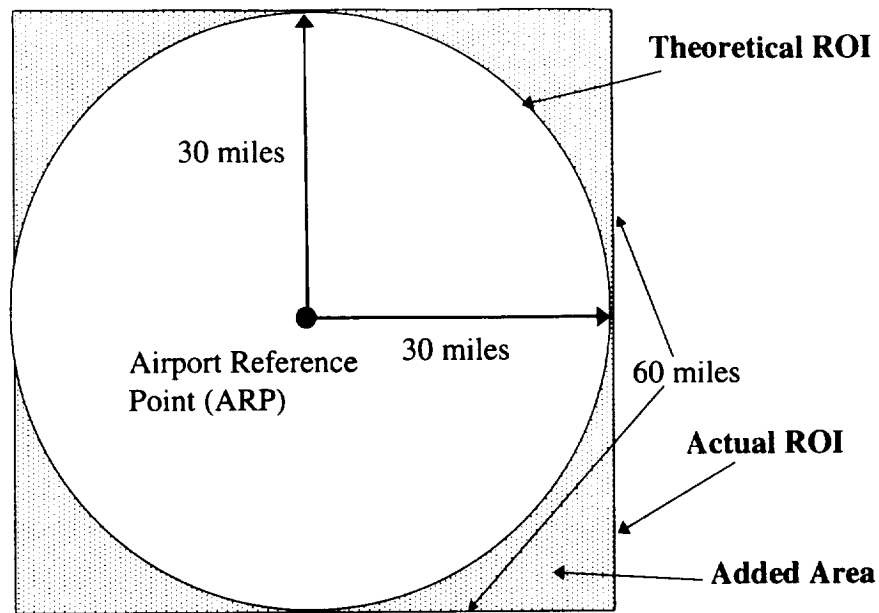
Figure 7 Region of Interest

After the ROI has been defined all of the ASMD cells within the ROI must be analyzed. The cells are analyzed sequentially starting from the southwestern most corner of the ROI and ending at the northeastern most corner of the ROI. Each cell is analyzed by finding all of the USGS elevations that are located within the ASMD cell. Approximately two hundred fifty six USGS elevations will be located for each ASMD elevation. **Figure 8** describes the location of ASMD and USGS elevations in an ASMD cell.

After the USGS elevations have been located they will be scanned to determine the maximum USGS elevation for the ASMD cell. If the ASMD cell does not contain any error, the elevation in the ASMD data file will be identical to the maximum USGS

elevation. **Equation 1** defines the error in the ASMD cell by taking the difference

between the ASMD elevation and the maximum USGS elevation.

$$ASMD_{ERROR} = USGS_{MAXelevation} - ASMD_{elevation}$$

Equation 1 ASMD Error

After the ASMD error is calculated it is stored in an error matrix. Each ASMD

cell will have an error associated with the cell. After the error has been stored, it is

determined if all the cells in the ROI have been analyzed. If all of the cells have not been

analyzed the next sequential ASMD cell in the ROI is analyzed. If all of the cells in the

ROI have been analyzed the methodology has been completed and a statistical analysis of

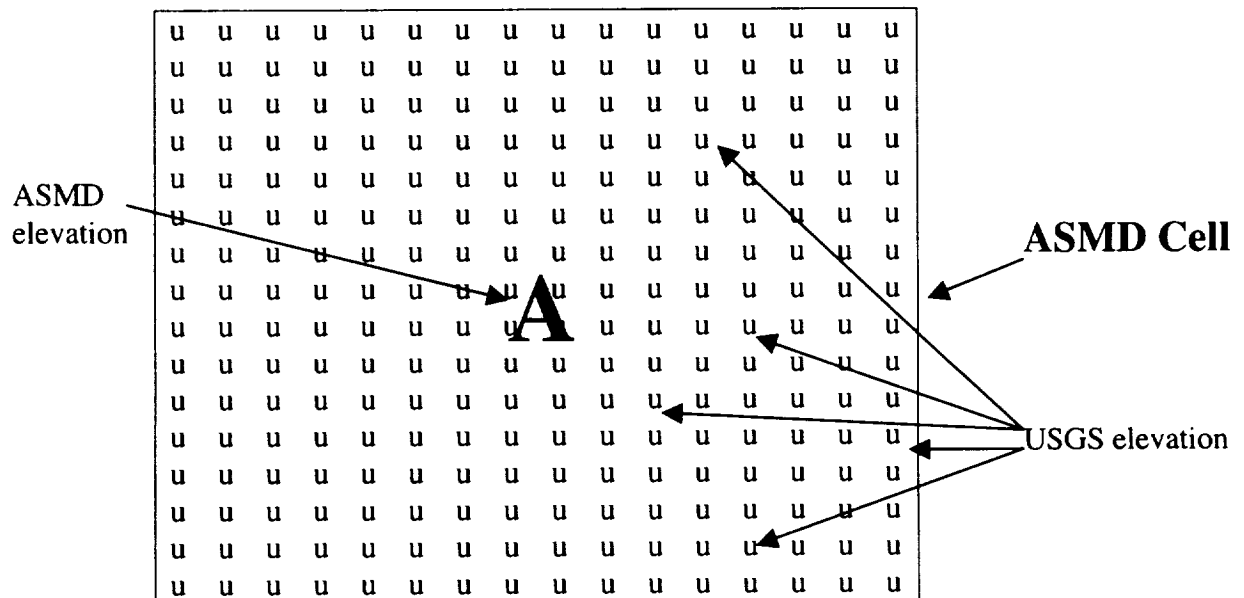the error matrix can be performed.

Figure 8 ASMD & USGS elevations

Buffer

The methodology must be modified to correct for the fifty meter horizontal

accuracy of the ASMD cell. The instrumentation that collected the data could possibly

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include an elevation within the fifty meter buffer of the cell as being within the cell The

fifty meter horizontal accuracy means that the geographical area within fifty meters of the

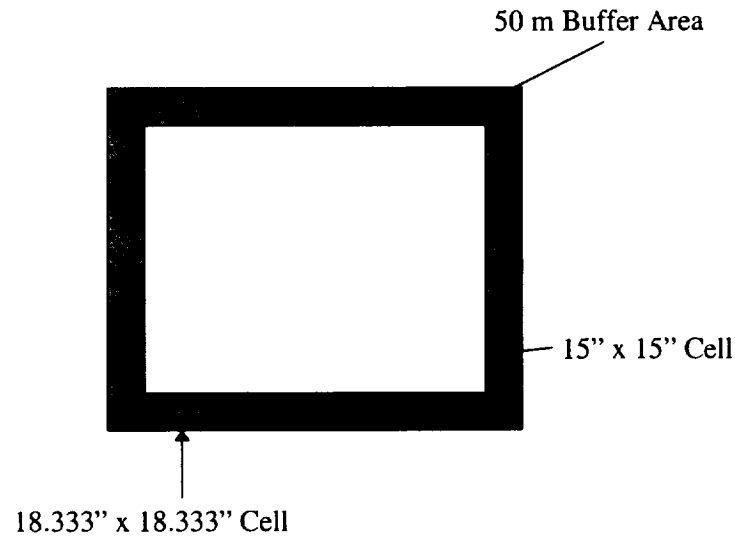ASMD cell boundary may contain the elevation (See **Figure 9**).

Figure 9 Modified ASMD Cell

The entire ASMD cell must be changed to correct for the horizontal accuracy.

The dimensions of the modified ASMD cell are eighteen and one third arc second by

eighteen and one third arc second (15" + (50+50)/30 = 18.333"). Due to the correction of

the buffer each ASMD cell will actually have more than two hundred fifty six USGS

elevations associated with the cell. The boundary of the ROI must be increased by fifty

meters to account for the horizontal accuracy.

Datum Shift

The methodology developed in this paper cannot be applied to the data without

correcting the datum shift. **Table 2** showed that the horizontal datum for the ASMD

database is the World Geodetic System of 1984 and the horizontal datum for the 7.5

minute DEM is the North American Datum of 1927. Since the databases have different horizontal datum, coordinates in one database do not correspond to the exact same coordinates in the other database.

The horizontal datum establishes the reference point from where the coordinates are projected. **Figure 10** is a .gif image taken from URL http://www.wgs84.com/wgs84/wgs84.htm. Latitudinal and longitudinal coordinates are relative to the horizontal datum from which they are projected. The latitudinal and longitudinal coordinates for a geographic region in the ASMD database will correspond to a different geographic region in the USGS database because of the difference in the horizontal datum. The datum shift could result in an elevation in the ASMD database being several arc seconds away from the corresponding elevation in the USGS database.
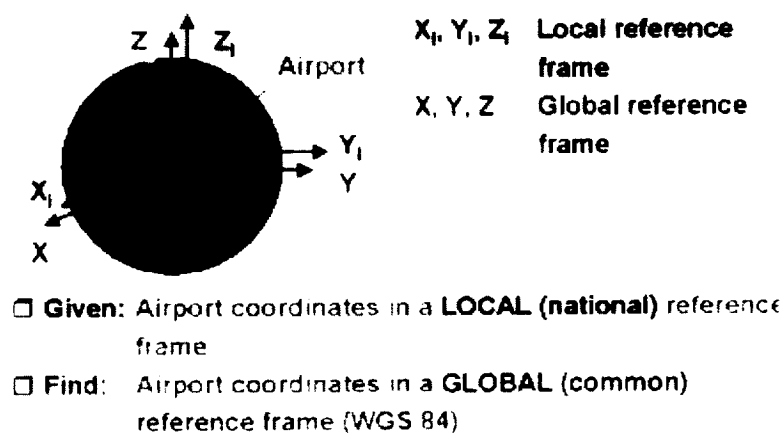

X_l, Y_l, Z_l **Local reference frame**

X, Y, Z **Global reference frame**

☐ **Given**: Airport coordinates in a **LOCAL (national)** reference frame

☐ **Find**: Airport coordinates in a **GLOBAL (common)** reference frame (WGS 84)

Figure 10 Datum Shift

The datum shift was corrected by modifying the coordinates of the USGS 7.5 minute DEM. The USGS coordinates have a higher accuracy and were projected into the ASMD coordinates to reduce error propagation. The correction for the datum shift was based on the ARP. MICRODEM software was used to determine the equivalent USGS

coordinates for the ASMD ARP. The latitudinal and longitudinal adjustments are then

used to correct the coordinates for the entire USGS data file.

Results

The methodology presented in this report was implemented by writing a computer

program using Microsoft Visual Basic 6.0.   **Appendix 2** is a printout of the computer

program. Data was collected and analyzed for five airports. **Table 3** lists the five

airports and their ARP. Latitudinal and longitudinal coordinates are relative to the

horizontal datum of WGS 84. The airports are located on the West Coast, East Coast and

Midwest of the United States.

Airport Name	State	Latitude	Longitude
Scappoose Industrial Air Park	Oregon	N45 46 21.0	W122 51 44.4
Denver International Airport	Colorado	N39 51 30.2	W104 40 01.2
Delta Municipal Airport	Utah	N39 22 59.8	W112 30 34.8
Asheville Regional Airport	North Carolina	N35 26 10.3	W082 32 30.5
McClellan-Palomar Airport	California	N33 07 41.6	W117 16 48.8

Table 3 ASMD Airports

Background

The program computed and stored the ASMD error, the maximum USGS

elevation for each cell, and the number of USGS posts located in each cell for the five

airports listed in **Table 3.** Microsoft Excel was used to calculate statistics from the

stored data and develop a histogram for the ASMD airports. Modifications were made

during the analysis that affected the computation of the statistics.

Some cells located in the ROI had less than two hundred USGS posts located

inside of it. Each cell located in the ROI should contain at least two hundred fifty six

USGS posts. If a cell had less than two hundred USGS posts it was discarded from the

calculations because it had insufficient data. The cell may have had insufficient data

because of collection techniques, bordering, the curvature of the earth and buffering.

Since some cells located within the ROI were discarded form the analysis it affected the derivation and computation of the statistics. The cells located in the ROI with more than two hundred USGS posts will be referred to as qualified cells.

Statistics

The average ASMD elevation in the ROI was calculated by determining the average of all the elevations located in the ROI. The ASMD error is calculated by subtracting the ASMD elevation from the maximum USGS elevation for each qualified cell. ASMD error was not calculated for non-qualified cells. The average ASMD error was calculated by taking the average of the ASMD errors for each airport.

The USGS elevation was calculated by taking the maximum of the USGS posts for each qualified cell. The USGS elevation was not stored for non-qualified cells. The average USGS elevation was calculated by taking the average of the USGS elevation for each airport. Due to the existence of non-qualified cells the average ASMD error is not necessarily equal to the difference of the average ASMD elevation and the average USGS elevation.

Tables 4–8 list the statistics for the five ASMD airports. The ASMD error, maximum USGS elevation and the number of USGS posts for each qualified cell are displayed (All calculated by computer program). The average, standard deviation, maximum, minimum, median and mode were calculated using Microsoft Excel. **Figures 11-15** are histograms for the airports.

SCAPPOOSE INDUSTRIAL AIRPARK			
	asmderror	usgselev	USGS posts
Average	11.73	237.56	249.11
Std	34.27	197.23	8.58
max	744	1363	280
min	-72	0	216
Median	6	196	247
Mode	18	2	247

Table 4 Scappoose Airport

The average ASMD elevation in the ROI at Scappoose airport was two hundred

twenty six meters (225.83 m). The average USGS elevation in the ROI was two hundred

thirty eight meters (237.56 m). The range of the USGS elevations was from one

thousand three hundred sixty three meters to zero meters. The ASMD error was twelve

meters (11.73 m).   **Figure 11** is a histogram of the ASMD error for Scappoose airport.
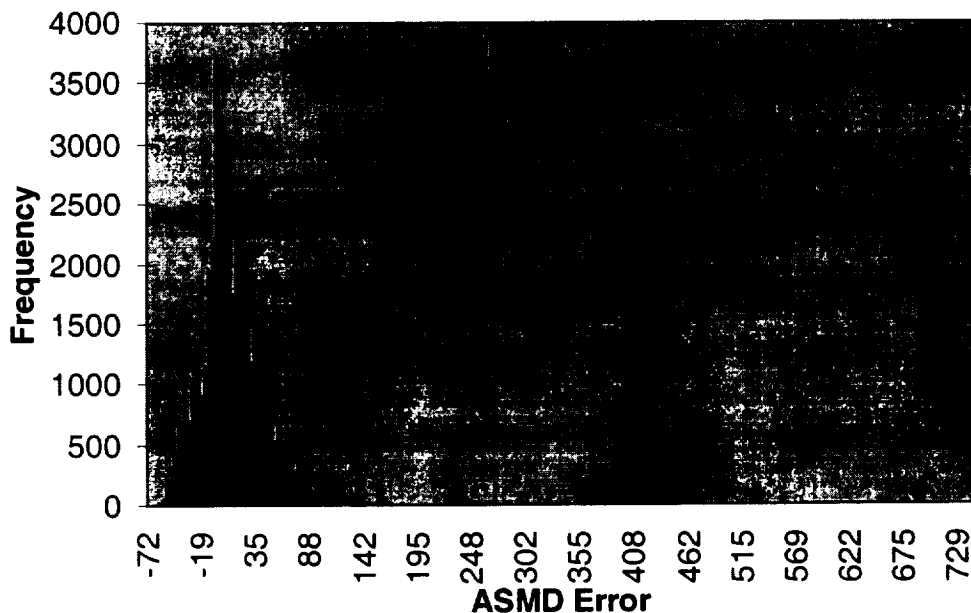

Figure 11 Scappoose Histogram

DENVER INTL			
	asmderror	usgselev	USGS posts
Average	6.34	1642.91	273.76
Std	10.26	149.20	10.32
max	115	2283	302
min	-43	1353	208
median	5	1620	271
mode	3	1679	285

Table 5 Denver Airport

The average ASMD elevation in the ROI at Denver airport was one thousand six

hundred thirty meters (1629.9 m). The average USGS elevation in the ROI was one

thousand six hundred forty three meters (1642.9 m). The range of the USGS elevations

was from two thousand two hundred eighty three meters to one thousand three hundred

fifty three meters. The ASMD error was six meters (6.34 m). **Figure 12** is a
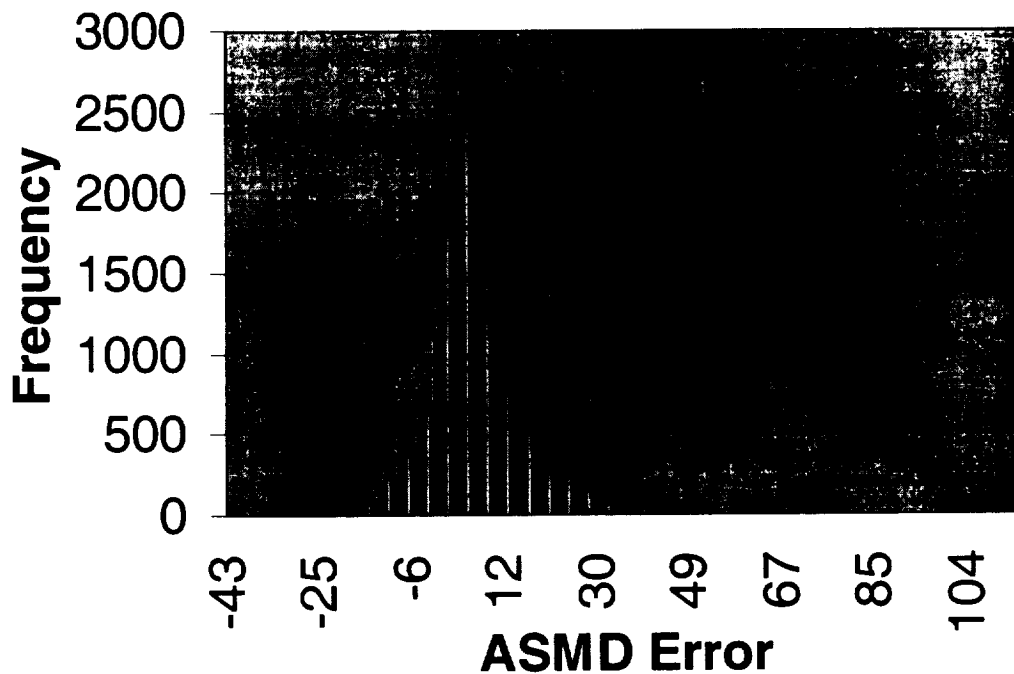
histogram of the ASMD error for Denver airport.

Figure 12 Denver Histogram

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DELTA MUNI			
	asmderror	Usgselev	USGS posts
Average	16.31	1600.62	275.67
Std	28.34	303.01	8.00
max	342	3083	285
min	-49	1380	201
median	7	1464	276
mode	-1	1392	285

Table 6 Delta Municiapal Airport

The average ASMD elevation in the ROI at Delta Municipal airport was one

thousand five hundred ninety meters (1589.86 m). The average USGS elevation in the

ROI was one thousand six hundred one meters (1600.62 m). The range of the USGS

elevations was from three thousand eighty three meters to one thousand three hundred

eighty meters. The ASMD error was sixteen meters (16.31 m). **Figure 13** is a histogram
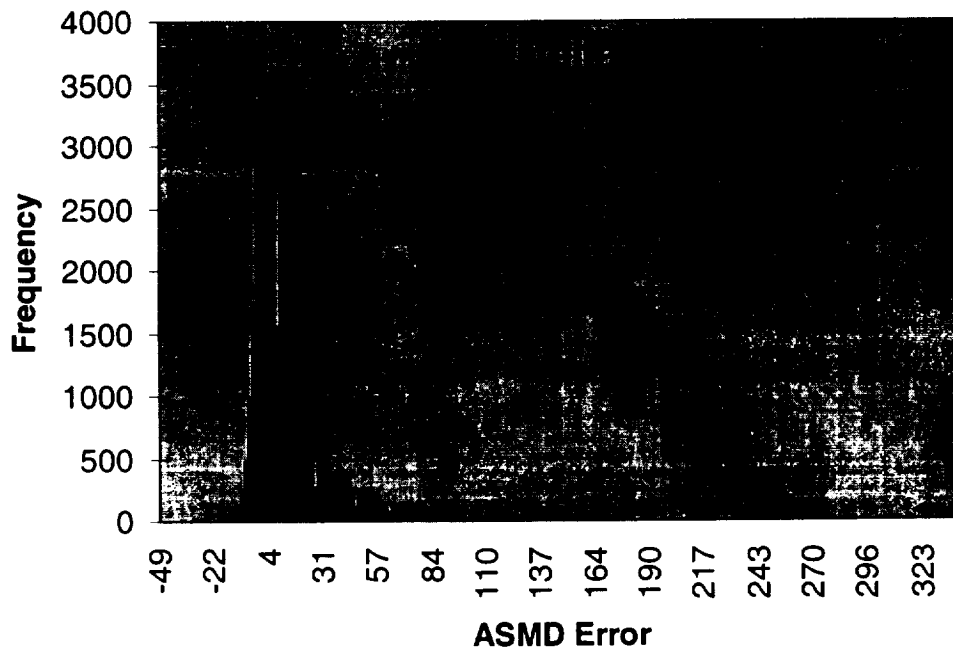
of the ASMD error for Delta Municipal airport.

Figure 13 Delta Municipal Histogram

ASHEVILLE REGIONAL			
	asmderror	usgselev	USGS posts
Average	42.91	843.56	289.11
Std	37.54	325.05	8.81
max	257	2029	304
min	-22	257	202
median	31	843	288
mode	13	978	285

Table 7 Asheville Regional Airport

The average ASMD elevation in the ROI at Asheville Regional airport was eight

hundred six meters (805.67 m). The average USGS elevation in the ROI was eight

hundred forty four meters (843.56 m). The range of the USGS elevations was from two

thousand twenty nine meters to two hundred fifty seven meters. The ASMD error was

forty three meters (42.91 m). **Figure 14** is a histogram of the ASMD error for Asheville
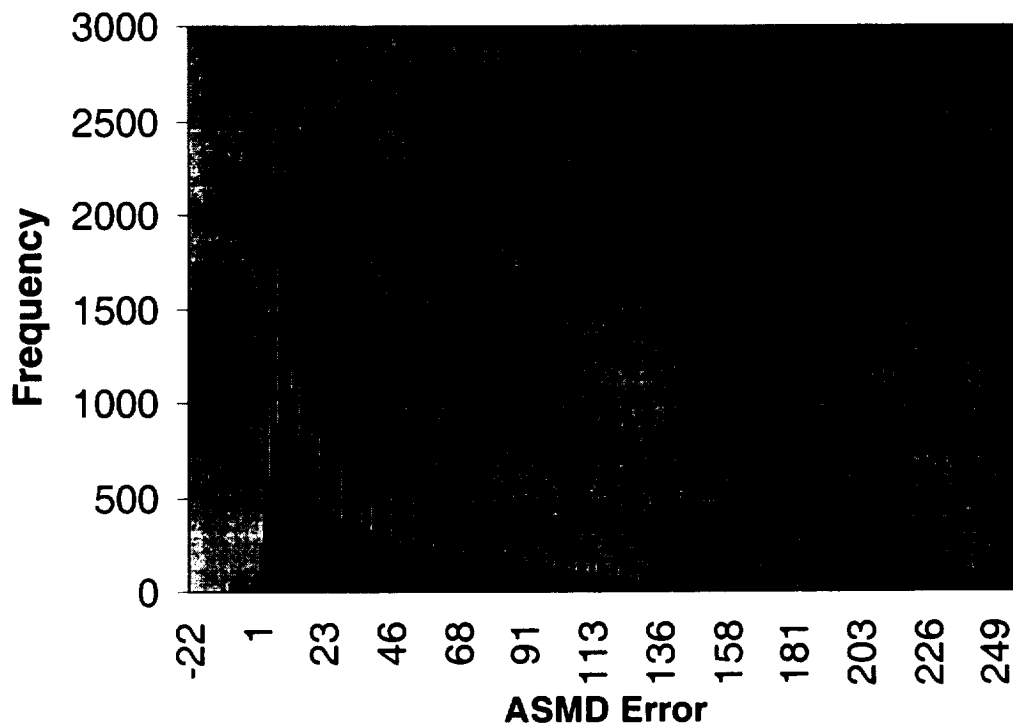
Regional airport.

Figure 14 Asheville Histogram

MC CLELLAN-PALOMAR			
	asmderror	usgselev	USGS posts
Average	30.07	339.39	297.76
Std	34.89	315.94	10.04
Max	608	1873	304
Min	-154	0	201
Median	22	258	304
Mode	0	0	304

Table 8 McClellan Airport

The average ASMD elevation in the ROI at McClellan-Palomar airport was two

hundred thirty three meters (232.67 m). The average USGS elevation in the ROI was

three hundred thirty nine meters (339.39 m). The range of the USGS elevations was from

one thousand eight hundred seventy three meters to zero meters. The ASMD error was

thirty meters (30.07 m). **Figure 15** is a histogram of the ASMD error for McClellan-
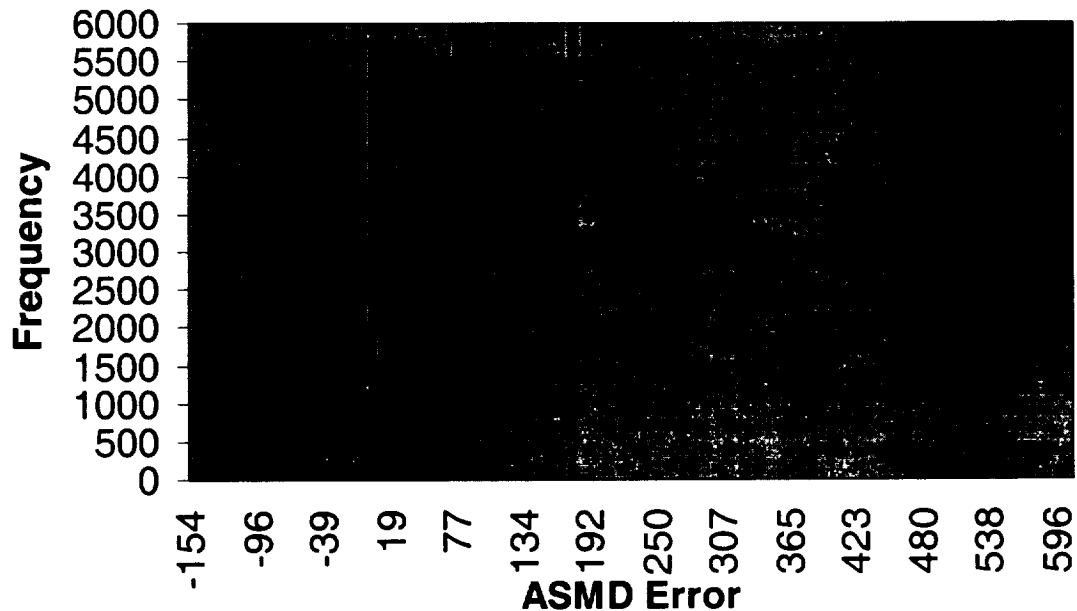
Palomar airport.

Figure 15 McClellan Histogram

Discussion

This section analyzes the ASMD error results. The Asheville histogram (See **Figure 14**) appeared to have several spikes imposed over a normal distribution. Upon review it was noticed that the spikes occurred every second or third bin and were caused by the way Microsoft Excel calculated the number of whole numbers in each bin (See **Table 9**). If Microsoft Excel had calculated bin widths so, that each bin would have the same number of whole numbers the spikes would have disappeared (See **Figure 16**).

Bin	Frequency	Whole Numbers Included in Bin
4.77	599	4
6.18	1763	5,6
7.59	882	7
9.00	2094	8, 9
10.41	1180	10
11.82	1063	11
13.23	1923	12, 13
14.64	826	14
16.05	1494	15, 16
17.45	567	17
18.86	550	18
20.27	1055	19, 20
21.68	478	21
23.09	879	22, 23
24.50	433	24
25.91	404	25
27.32	817	26, 27
28.73	375	28

Table 9 Asheville Bin Width

The histogram for the McClellan airport (See **Figure 15**) had an unusually large spike. The spike can easily be explained by investigating the geography of the airport. Almost thirty percent of the McClellan airports ROI contained the Pacific Ocean. The

ASMD error for a cell located in the Pacific Ocean is zero. The bin with the large spike

contained zero for its ASMD error.

The average ASMD error for all five airports is positive. The author anticipated

these results because the 7.5 minute DEM sampled more elevations in the cell than the

ASMD. The larger the number of samples in the cell the more likely you are to obtain
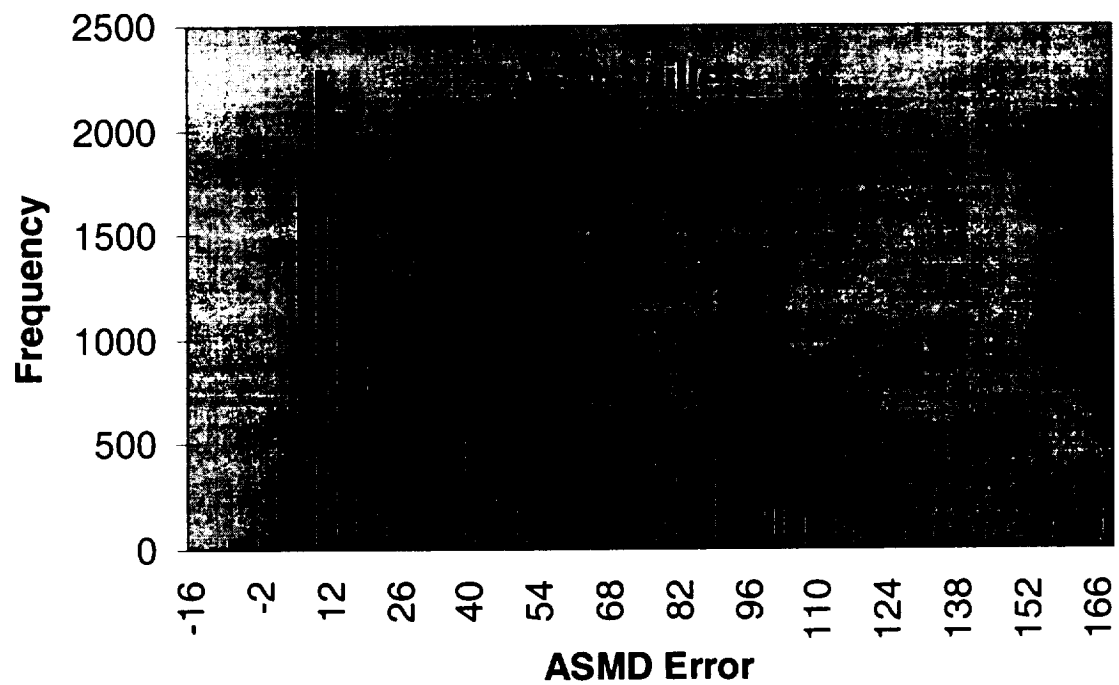
the maximum.

Figure 16 Modified Asheville Histogram

Summary

The three objectives of this report were accomplished. The USGS was utilized as the benchmark database. A methodology to measure error was developed and implemented by writing a computer program. Data reduction was achieved through the use of descriptive statistics.

Five airports were investigated during the study. The average ASMD error ranged from six meters (Denver) to forty-three meters (Asheville). The publishers of ASMD claimed that ninety percent of the elevations are within thirty meters of the actual elevation. Four of the five investigated airports had average errors that were less than thirty meters. More airports need to be studied before I can accept or reject the publisher's claim of ninety percent of the elevations falling within thirty meters of the actual elevation.

Recommendations for future work include using hypothesis testing. The publishers claim could be used as the null hypothesis. The number of airports could be increased to include a more representative sample of the terrain impacted airports. Percentiles of the ASMD error could be developed to enhance the understanding of the data.

The primary limitation of this report is that it only analyzed the qualified ASMD cells located in the ROI. An area of future work would include developing a methodology to measure the error in the non-qualified ASMD cells. This report only analyzed the ASMD cells that had at least two hundred USGS elevations. If the non-qualified cells could be studied the entire region of interest could be analyzed.

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Appendix 1 ASM100 Header

Header File Version 2.0
Product = Airport Safety Model (ASM)
Creation Date = 1998149   05/29/1998
Produced by = Office of Aeronautical Charting and Cartography, U.S. Government
//
Site ID = DEN
Model Type = ASM100
Site Number = 02573.000*A
Airport Name = DENVER INTL
City = DENVER
State = CO
Country = US
ARP Latitude =   N39 51 30.2
ARP Longitude = W104 40 01.2
Northern Model Boundary = N40 41 45
Southern Model Boundary = N39 01 15
Eastern Model Boundary = W103 34 00
Western Model Boundary = W105 46 00
Degree Blocks North-South = 2
Degree Blocks East-West = 3
Bin Rows =   402
Bin Columns = 528
Bin Resolution in seconds North-South = 15
Bin Resolution in seconds East-West =   15
Maximum Model Elevation in meters = 4344
Minimum Model Elevation in meters = 1269
//
Source Data = DTED-1
  Source Data Code = A1
  Source Data Horizontal Datum = WGS84
  Source Data Vertical Datum = MSL
  Source Data Horizontal Accuracy Objective = +- 50 Meters at 90% CE
  Source Data Vertical Accuracy Objective = +- 30 Meters at 90% LE
// Note: Accuracy statements of DTED source data are provided by the
// National Imagery and Mapping Agency (NIMA), which specifies that such
// statements are individually calculated for every product, and provided
// in the Accuracy Header Record of those products. Concerning the Airport
// Safety Model (ASM), which is based on this data, no greater accuracy is
// implied or should be assumed.
//
Source Data = Not Available
  Source Data Code = NA
// Note: Default elevation = -999 when source data is unavailable.
//
File Structure:
        Field Name   Format   Bytes
Field 1: Meters above\below Mean Sea Level   NNNN   4
Field 2: Latitude   ANNNNNN   7
Field 3: Longitude   ANNNNNNN   8
Field 4: Data Source Code   AA   2

Field 5:   End-of-Line   0D0A[Hex]   2
// Note: Each record corresponds to a different model bin. Bin records are
// listed from south to north, starting at the western edge of the model and
// proceeding east. Delimiters (AAAA NNNNA) are placed at the start of each
// column.
//
#EOH
Clmn 0001:
2685N390127W1054600A1
2687N390139W1054545A1

Appendix 2 Computer Program Printout

```
Private TextLine As String, t2 As String, t3 As String, t4 As String, i As Integer, elev As
Long, usgspts As Long, lat(10500000) As Single, lng(10500000) As Single,
elv(10500000) As Single, dlng As Single, asmdlat(70000) As Single, asmdelev(70000)
As Single, asmdlong(70000) As Single, asmderror(70000) As Single
Public number As Long, duration As Date, j As Integer, jj As Long, nlat As Single, slat
As Single, elong As Single, wlong As Single, ROI As Single, q As Long, datafile As
String, ii As Long, nn As String
Private Sub cmdstart_Click()
openasmd
ROIboundary
openheader
opendatafile
DoEvents
pbar.Max = Val(Right(Text7, 4))
openusgs
readasmd
Text6.Text = elev / number
Close #1
pbar.Visible = False
Rem nn = InputBox("How many cells do you wish to sample in the ROI do you wish to
sample? ", "Sampling", number)
nn = number
If nn < number Then sample
If nn = number Then nosample
Close #3

TextLine = cdb.FileName            'airport name


        'mean elevation
Text8 = DateDiff("s", duration, Now)        'time to read data
DoEvents

CmdUSGS.Visible = True
End Sub

Private Sub CmdUSGS_Click()
End
End Sub

Private Sub openasmd()
cdb.ShowOpen
CmdStart.Visible = False
j = 0
Open cdb.FileName For Input As #1
k = 0
elev = 0
```

```
End Sub

Private Sub openheader()
Dim x As Single
duration = Now              'sets initial time
Text8 = duration
For i = 1 To 58
Line Input #1, TextLine
If i = 22 Then Text7 = TextLine '# of rows
If i = 13 Then Text10 = Right(TextLine, 11) 'latitude arp
x = convert(Text10, 10)
Text12 = "N" & x
nlat = x + ROI  'region of interest
Text17 = "N" & nlat
slat = x - ROI  'region of interest
Text15 = "N" & slat
If i = 14 Then Text11 = Right(TextLine, 12) 'longitude arp
x = convert(Text11, 11)
Text13 = "W" & x
elong = x + ROI 'region of interest
Text16 = "W" & elong
wlong = x - ROI 'region of interest
Text14 = "W" & wlong
If i = 9 Then Text9 = Mid(TextLine, 16, 30) 'airport name
Next i
End Sub

Private Sub readasmd()
Do While Not EOF(1)
Line Input #1, TextLine

pbar.Value = j
Text5.Text = j                'column index
t2 = Left(TextLine, 4)    'elevation
If t2 = "Clmn" Then            'column check
   j = j + 1
   Text8 = DateDiff("s", duration, Now)
   DoEvents
            Else
   t3 = Mid(TextLine, 5, 7)  'latitude
   t3 = convert(t3, 6)
   If t3 > slat And t3 < nlat Then
      t4 = Mid(TextLine, 12, 8) 'longitude
      t4 = convert(t4, 7)
        If t4 > wlong And t4 < elong Then
            number = number + 1     'Region of interest
```

```
            Text18 = number
            elev = elev + Val(t2)
            asmdlat(number) = t3
            asmdlong(number) = t4
            asmdelev(number) = t2


        End If
    End If


End If


Loop
End Sub


Public Function convert(ByVal T10, n) As Single
Dim dummy As String
Dim x As Single, y As Single, z As Single
dummy = Right(T10, n)
x = Val(dummy)
convert = Int(x / 10000)
y = Int((x - convert * 10000) / 100) / 60
z = (x - convert * 10000 - y * 6000)
convert = convert + y + z / 3600
convert = Int(convert * 10000 + 0.5) / 10000
End Function




Private Sub Form_Load()
MMControl1.Visible = False

End Sub

Public Sub findusgsdata()

Dim nbound As Single, sbound As Single, wbound As Single, ebound As Single,
maxpost As Single, zz As Integer
Rem radius is .0020833 and buffer is .0004629
nbound = t3 + 0.0025462
sbound = t3 - 0.0025462
wbound = t4 + 0.0025462
ebound = t4 - 0.0025462
maxpost = -100000
zz = 0
For jj = 1 To usgspts
```

```
Input #2, dlng, ddd, eelv
If ddd < ndlat Then
    If ddd > sdlat Then
        If -dlng > wdlong Then
            If -dlng < edlong Then
                usgspts = usgspts + 1
                lng(usgspts) = -dlng + 0.0008 'datum adjustment
                lat(usgspts) = ddd - 0.0001    'datum adjustment
                elv(usgspts) = eelv
            End If
        End If
    End If
End If
Loop
Close #2
Text19 = usgspts
t27 = 0
t28 = 230
t24 = 0
t25 = 250
For ii = 1 To 20
Beep
Next ii
For ii = 1 To usgspts
If lng(ii) < t28 Then t28 = lng(ii)
If lng(ii) > t27 Then t27 = lng(ii)
If lat(ii) > t24 Then t24 = lat(ii)
If lat(ii) < t25 Then t25 = lat(ii)
Next ii
Text24 = t24
Text25 = t25
Text27 = t27
Text28 = t28
Text23 = elv(Int(usgspts / 2))
DoEvents
End Sub

Public Sub ROIboundary()
XROI = InputBox("What is the radius for the Region of Interest (ROI)for the ASMD",
"ROI Radius", 0.44706)
ROI = CSng(XROI)
End Sub


Private Sub sample()
```

```
Dim z As Long


Text8 = DateDiff("s", duration, Now)
Write #3, "ASMD ROI average elevation is "; Text6
Write #3, "counter"; "asmdlat"; "asmdlong"; "asmdelev"; "asmderror"; "usgselev";
"USGS posts", "ERROR"

For ii = 1 To nn 'sample n cells from a population of number cells
Randomize
Text21 = ii
z = number - ii + 1      'Upper bound of set, deacrements each iteration
q = Int(z * Rnd + 1) 'Pick a random # from 1 to n-ii
t3 = asmdlat(q)
t4 = asmdlong(q)
elev = asmdelev(q)
findusgsdata

Rem swap selected cell out of set to ensure no duplication
asmdlat(q) = asmdlat(z)
asmdlong(q) = asmdlong(z)
asmdelev(q) = asmdelev(z)

DoEvents

Next ii
End Sub


Public Sub opendatafile()
datafile = InputBox("What name do you wish to use for an output file?", "Select Output
File", Text9)
datafile = "c:\" & datafile & ".dat"
Open datafile For Output As #3

Write #3, Text9

DoEvents
End Sub


Public Sub nosample()
Dim z As Long
```

```
Text8 = DateDiff("s", duration, Now)
Write #3, "ASMD ROI average elevation is "; Text6
Write #3, "counter"; "asmdlat"; "asmdlong"; "asmdelev"; "asmderror"; "usgselev";
"USGS posts", "ERROR"

For ii = 1 To nn 'sample n cells from a population of number cells

Text21 = ii

q = ii
t3 = asmdlat(q)
t4 = asmdlong(q)
elev = asmdelev(q)
findusgsdata



DoEvents

Next ii
End Sub
```